Testimony before the House Subcommittee on
Fisheries Conservation, Wildlife, and Oceans

On

The Impact of Climate Change on Coral Reef Ecosystems

Coral Reefs under Multiple Stresses in an Era of Climate Change

John C. Ogden
Director, Florida Institute of Oceanography
Professor of Biology, University of South Florida

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My name is John C. Ogden. I am Director of the Florida Institute of Oceanography (FIO) and Professor of Biology at the University of South Florida. We are a 17-member consortium of universities, agencies, and marine laboratories, which operates two ships and a marine laboratory and administers and leverages funding for inter-institutional projects in research and education on coral reefs and in coastal oceans in Florida and the greater Caribbean Sea. I have spent my career of over 30 years working on coral reefs all over the world, introducing students and the public to their beauty and their importance to science and society. I had a role in the design of the International Coral Reef Initiative and the implementation of the Global Coral Reef Monitoring Network. I served as the Secretary of Commerce's appointee for science on the founding Advisory Council of the Florida Keys National Marine Sanctuary. I am the ex-president of the International Society for Reef Studies, a 750-member organization of scientists, resources managers and conservationists from over 50 countries dedicated to the scientific understanding and protection of coral reefs. I currently serve on the Boards of the World Wildlife Fund and The Ocean Conservancy and am a Fellow of the American Association for the Advancement of Science.

I am honored to be here to testify on coral reefs before this Subcommittee for the second time. I remain acutely conscious that we have a narrow window of time in which to establish an integrated national strategy to conserve our nation's coral reefs and to influence other nations, with far more of the world's reefs, to do the same.

Background: Are coral reefs doomed?

I first testified before this Subcommittee in 1999 on the Coral Reef Conservation Act, which was our nation's response to the International Coral Reef Initiative, established under U.S. leadership in 1995. Since then, the Coral Reef Task Force has produced The National Action Plan to Conserve Coral Reefs-- a comprehensive statement of the scope of coral reef problems. Under the Coral Reef Conservation Act of

2000, key agencies including NOAA and the Department of the Interior have action plans and statements of capability at various stages of preparation. This national effort has been backed up by international coral reef status reports and calls for action. Yet we still do not have a coherent national strategy of conservation, management, and research on coral reefs.

Against this background, coral reefs have continued to decline, most dramatically in the global coral bleaching event of 1997-98, coincident with the El Niño of the century. This event and the growing public concern with climate change is increasing the pressure for a long-term, comprehensive energy national policy including CO_2 emissions into the atmosphere as outlined in the Kyoto Protocol. However, even if we implemented such a policy today the lag times are significant and there is considerable pessimism about the future of coral reefs even under the most optimistic scenarios of emissions control.

It is legitimate to ask the question: Are coral reefs doomed? No one knows the answer. However, through our history we as a nation have often been in the position of being able to see that things are hopeless and yet we remain determined to make them otherwise. I am convinced that good science, common sense, and integrated policy can make the difference for coral reefs.

Recommendations

- Implement with adequate funding the National Action Plan to Conserve Coral Reefs through the detailed action strategies of key agencies, particularly NOAA, the Department of the Interior, and the Environmental Protection Agency.
- Use the Executive Order on Marine Protected Areas, the Coral Reef Conservation Act, the Oceans Act, and the essential fish habitat and ecosystem protection provisions of the Fisheries Management Act to push forward with large, ecoregional zoning and protection plans, particularly in the Northwest Hawaiian Islands Coral Reef Reserve, other Pacific territories, and in the Caribbean Sea.
- Support the implementation of the Integrated and Sustained Ocean Observing Network, now in the advanced planning stages, in conjunction with ecoregional coral reef zoning plans.
- Support a program of Ocean Conservation and Management Science within the NSF deliberately directed at the partnering of federal agencies and academic scientists in the understanding of the impact of climate change and other human disturbances on large marine ecosystems.
- Use the extraordinary charisma of coral reefs to implement education programs informing people of the problem of human disturbances to coral reefs and to the oceans and their role in the solutions, including the need for a comprehensive national energy policy dealing directly with climate change.

Coral Reefs in an Era of Climate Change

The coral bleaching response to climate change first appeared on the policy stage in the summer of 1987, coincident with a major international episode of bleaching, increasing concern about global warming, and one of the warmest years on record in Washington, DC. The Senate held hearings on coral bleaching and testimony reported preliminary scientific evidence that linked bleaching with unusually warm seasonal seawater temperatures.

Corals bleach when stresses, including high temperatures, stimulate the coral animal to expel its intra-cellular single-celled plant symbionts, which are characteristic of all reef-building corals and critical to coral

health. As the color of corals is determined in large part by the plant cells, the corals appear to bleach. Bleaching does not immediately kill corals and they are capable of recovery if the stress is removed, but if it is prolonged corals may die.

Since 1987 episodes of bleaching increased in geographic extent and severity. Bleaching was associated with the El Niño-Southern Oscillation (ENSO) which had come to be recognized as driving global climate patterns. Research in the late 1980's and 1990's strengthened the link between bleaching and seasonally warm seawater temperatures and corals were called "canaries in the cage" (after the canaries used by 19th century coal miners to detect poison gases)-- harbingers of global warming in the oceans.

Coral bleaching isn't the only detrimental effect of climate change on coral reefs. Prolonged seasonally warm temperatures stress corals and can increase the growth rate of the potentially pathogenic microorganisms responsible for coral diseases. Increased CO_2 in the atmosphere lowers the saturation state of calcium carbonate ($CaCO_3$) in the ocean. This has been shown to decrease coral reef calcification and may over time be an even more important factor than bleaching in the global adjustment of coral reefs to climate change. Another recent hypothesis links long-term drought in the Sahel region of Sub-Saharan Africa with increased deposition of dust carried across the Atlantic to the Caribbean by prevailing westerly winds. The dust contains iron, which has been shown to stimulate planktonic algal blooms. It may also be inimical to coral health and stimulate the growth of benthic algae. The dust may also contain coral pathogens such as fungi and bacteria.

In 1997-98, coincident with the ENSO of the century, corals all across the world's tropics bleached and many died. This was arguably the most coherent response we have ever seen of a global ecosystem to a disturbance linked to human activities. This unprecedented episode of bleaching touched areas that had rarely experienced bleaching before, including parts of the Great Barrier Reef of Australia. The event was well covered by the global press and caused great concern. It is disturbing, however, that in spite of solid scientific evidence linking bleaching to ocean warming, we ignored the fall of the canary from its perch. Now, while it is twitching on the bottom of the cage, we prevaricate about the human role in climate change.

Coral Reefs Under Multiple Stresses: A Thousand Cuts

Human activities influence coral reefs in a variety of ways, but the general categories of disturbances make a remarkably short list:

1. Climate change including ocean warming, sea level rise, and increased atmospheric CO_2.
2. Land-based sources of pollution, including land destabilization and sedimentation, sewage disposal, toxic pollution, and pathogens.
3. Over-fishing, including both the consequences of removal of fishes from reefs and the damage of fishing techniques and gears.

Note that these disturbances operate on distinctly different geographic scales. Climate change is the only global influence in the list and is the umbrella under which all other stresses to reefs operate. Land-based sources of pollution are both regional and local. For example, a significant proportion of marine pollution is aerosols and runoff originating far from the ocean. Over-fishing is largely a local problem and responds to relatively simple if not easily implemented management regimes. Finally, note that these disturbances are

characteristic not only of coral reefs but any coastal ocean area near human populations.

A Human Health Analogy

Imagine a coral reef as a patient with general ailments visiting the doctor. The doctor, whose degree is Medical Arts and Sciences, first takes a medical history and conducts a general examination of vital signs. The doctor is informed by science but, assuming the absence of an acute condition requiring immediate intervention, is guided as much by experience and common sense. The diagnosis might include a listing of the stresses of modern life: a high pressure job, not enough sleep, poor diet, too much coffee or alcohol, and so on. Medicine operates on the principle that reduction of stresses is good and that it helps the patient cope with stresses that she or he cannot or will not address.

I believe that the diagnosis of ecosystem health operates in the same way. I can think of no coral reef in the world where a few informed people, including, but not limited to scientists, could not come to reasonable conclusions as to the sources of disturbances to the reef and reasonable if not easy suggestions for conservation or management action. These actions will necessarily be limited to human disturbances that can be managed locally or regionally and will not address the umbrella stress of climate change. Nevertheless, the inference, perhaps an article of faith, is that reducing the impacts of pollution and fishing, for example, will make the reef better able to cope with climate change.

Science has already provided us with sufficient data and information to recognize a coral reef crisis. We must act by facing scientific uncertainty and using the precautionary principle. The National Action Plan to Conserve Coral Reefs implicitly assumes that future research on coral reefs should be done within the context of national programs of conservation, management, and education. A national research program, including but not limited to coral reefs, in Ocean Conservation and Management Science would include: (1) connectivity or seascape ecology at wide geographic scales; (2) ecological resilience and the functioning of biodiversity; and, (3) global climate change. This program could be based at the NSF with the cooperation of other agencies.

The Ecoregional Approach: Reefs Do Not Live Alone

Reefs are connected to the land and to other coastal ecosystems in a "seascape" of linked ecosystems (**Figure 1**). In addition to the exchange of energy and materials via transport processes and the movements of organisms, the ecosystems of the coastal seascape act as buffers. The landward seagrass beds and coastal forests buffer offshore coral reefs from the inimical influences of sedimentation and nutrients originating on land. In turn, offshore coral reefs buffer the nearshore ecosystems from the effects of ocean waves and erosion. Human interference with this buffering capacity has damaged coral reefs, smothering corals with destabilized sediments and promoting the growth of algae thorough excessive nutrients. Maintaining and restoring a fully functioning coastal seascape is a major goal of coral reef restoration.

Figure 1: The Coral Reef Coastal Seascape

Not all land influences are local. So-called "dead zones" on coastal shelves off the mouths of major rivers have been reported around the world. For example, massive algal blooms fertilized by runoff from agricultural areas far inland create the seasonal dead zone off the mouth of the Mississippi River in the Gulf of Mexico. In addition, a major component of marine pollution (up to 50% in some estimates) is from aerosols, which may originate many miles away from where they are deposited.

Coral reefs are connected to each other over large regions by ocean currents (**Figure 2**). For example in the Caribbean, remote sensing has shown that the outflow of the Orinoco River in Venezuela seasonally moves across the entire Caribbean Sea as far as Puerto Rico and perhaps beyond. These currents can carry marine organisms, with larval lives ranging from several weeks to over a year, over long distances. Of course, currents can also carry pollutants.

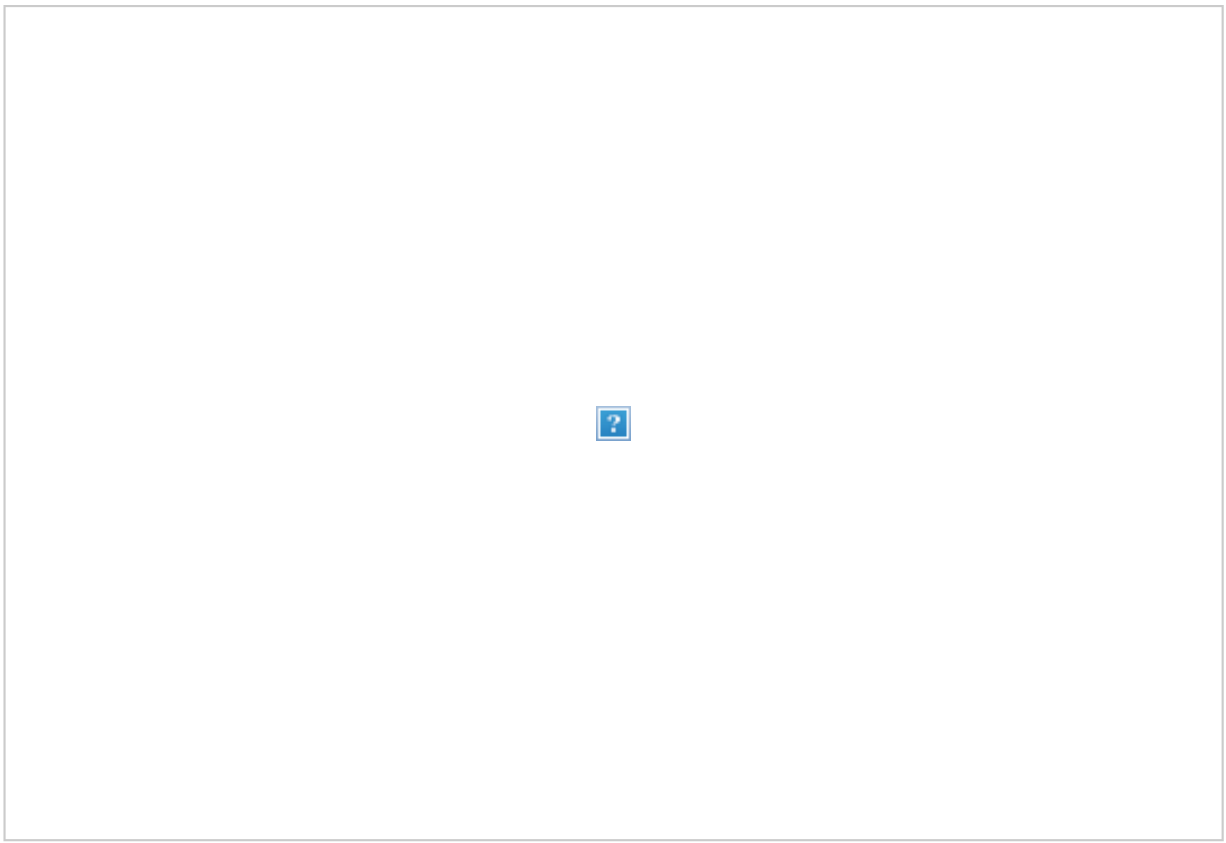

Figure 2: Ocean Currents in the Greater Caribbean Ecoregion

The importance of understanding ocean currents and other physical features of the ocean have driven the development of an Integrated and Sustained Ocean Observing System (IOOS) which should be supported by the Congress. While physical features are basic, we must include key features of the biology of the oceans, including coral reefs, in the national monitoring scheme.

A Lesson in Ocean Zoning

Over-fishing has grown in scientific and public concern. Recent work has suggested that fishing was the first human disturbance to coral reefs, altering their functioning long before the modern era. Coral reef fishes exert top-down control of reef ecosystems. The elimination of the larger size classes of predatory groupers and snappers, for example, causes population increases of fishes lower in the food chain, changing the natural functioning of the reef. Fishing has a major impact because most reef fishes are extraordinarily sedentary, associated with particular reef areas for their whole lives.

Fishing with explosives and toxic chemicals including bleach and cyanide has laid waste to huge regions of reefs in Indonesia and the Philippines and stimulated a variety of international management and conservation efforts. Fishing gears can damage reef areas and lost nets and line damage and destroy corals and entangle fishes and invertebrates.

These concerns have driven a rapidly increasing interest in marine protected areas, particularly marine reserves fully protected from all extractive human activities. In every case where fully protected marine reserves have been implemented, the result within a relatively short time has been more and larger fishes. Most of our current fully protected marine reserves in coral reefs areas are in the Florida Keys National Marine Sanctuary.

It is important to note, however, that marine protected areas are concerned about protection of the whole ecosystem, not just fishes. For example, The Nature Conservancy and World Wildlife Fund examined areas of the world which escaped the devastating impact of the 1997-98 coral bleaching episode. These include: areas where upwelling cools the water; areas of strong currents; regions where existing stresses have caused corals to adapt to extreme conditions; areas where corals are shaded by steep islands or by turbid waters. Strategically networked marine protected areas including these special situations might have the best possibility of mitigating the impact of climate change over time.

Ecoregional Planning: A Vision of the Future

Marine protected areas are necessary, but not sufficient. We should implement ecoregional plans to protect and manage coral reefs in which the whole country, not just fishing, has a stake. We have some excellent case studies of how this might be done. The Florida Keys National Marine Sanctuary management plan was a 7 year process involving a broad cross section of stakeholders in a plan that is based upon zoning, including but not limited to fully protected marine reserves. The plan includes water quality management and 8 other action plans dealing with everything from education, channel marking, recreational boat use, to high seas commercial ship traffic.

The Meso-American Coral Reef project of the World Wildlife Fund and the World Bank is the most advanced international ecoregional planning project involving coral reefs. The presidents of Mexico, Belize, Guatemala, and Honduras signed the Tulum Declaration in 1998, agreeing to co-manage the region. Subsequently, a series of major international planning exercises were held in which major features of the region including ocean currents, river drainages and key resources were mapped with population centers, industrial areas, marine discharges, existing protected areas and so on. Overlay maps provide the basis for decisions on protection and development which have every hope of leading to sustainable use of this major global coral reef region. It should not escape our attention that the Meso-American Coral Reef is directly upstream from Florida.

The Northwest Hawaiian Islands Coral Reef Ecosystem Reserve is a critical coral reef region for the nation. It is equivalent in size to the Great Barrier Reef Marine Park of Australia and far enough to the north to escape major coral bleaching episodes. It is virtually unpopulated and protected by distance from major fisheries. The Ocean Conservancy has identified it as a premier site for protection under their Ocean Wilderness campaign. Following on the examples of the Florida Keys and the Meso-American Coral Reef, the next steps should be involvement of the broad range of stakeholders in a major ocean use planning project.

Conclusions

Some scenarios for coral reefs in this era of climate change are not optimistic. However, there is a great deal of scientific uncertainty about the reef response and ample opportunity to implement local and regional reef protection schemes which may be our best prospect to mitigate climate change in the near term. At the

same time, we should use the lessons of coral reefs to argue for implementation of a comprehensive, long-term national energy policy which directly addresses climate change. There is every reason to expect that this will have beneficial social and economic impacts even if there may be a considerable lag in reef mitigation. We have had over a decade of discussions, research, planning, meetings, workshops, and status reports. There is sufficient scientific information. We should act now.

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